Ocean Ecology Branch Statement of Work

The Ocean Ecology Branch (OEB) at Goddard Space Flight Center (GSFC) is a world leader in satellite remote sensing of ocean biology and biogeochemistry, and engages in fundamental research in marine biogeochemistry and ocean ecosystem dynamics. The OEB is home to the Ocean Biology Processing Group (OBPG), which is responsible for the calibration, validation, software development, data processing, and distribution for ocean color products from a variety of spaceborne radiometers, including NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) currently operating on the Terra and Aqua spacecraft, legacy sensors such as the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) and the Coastal Zone Color Scanner (CZCS), and international missions such as Europe's Medium Resolution Imaging Spectroradiometer (MERIS), Japan's Ocean Color and Temperature Scanner (OCTS), and India's Ocean Color Monitor 2 (OCM2). A primary goal of the OEB is to produce a long term, continuous climate data record of ocean biological and biogeochemical products from satellite ocean color measurements spanning multiple missions, which requires continuous monitoring and improvement of instrument calibration and processing algorithms, as well as a rigorous validation and quality assessment effort. The OEB typically performs a reprocessing of all ocean color missions every two years, to incorporate improvements in instrument characterization knowledge or processing algorithms, or to incorporate new derived products into the distribution.

The processing capabilities of the OEB are also leveraged to support Sea Surface Temperature (SST) production from MODIS, evaluation of ocean color products from the Visible and Infrared Imager Radiometer Suite (VIIRS) that is soon to be launched on the National Polar Orbiting Environmental Satellite (NPOES) Preparatory Project (NPP), and production and distribution of Sea Surface Salinity (SSS) and Wind Speed products from Aquarius. After launch and the successful commissioning of the Aquarius instrument, Aquarius Project Management will transition from JPL to GSFC, and OEB staff will be responsible for the ground processing system, data distribution, and instrument scheduling and telemetry monitoring and anomaly detection for Aquarius. For NPP, the OEB is home to the Product Evaluation and Analysis Tools Element (PEATE) for oceans. The OEB is also actively engaged in new instrument and new mission development, which currently includes leading the preliminary science and sensor requirements development for the ocean color capabilities of the Aerosol Clouds and Ecosystems (ACE) and the Geostationary Coastal and Air Pollution Events (GEO-CAPE) missions identified in the 2007 NRC Decadal Survey for Earth Science (http://decadal.gsfc.nasa.gov/), as well as the Pre-ACE (PACE) data continuity mission recently announced by NASA. The OEB further participates in oceanographic field data collection and analysis to support the calibration, validation, and algorithm development for current and future satellite ocean color missions, and to support fundamental research in ocean ecosystem dynamics and biogeochemical processes. Much of the work performed within the OEB is detailed on the Ocean Color Web (OCW) at

http://oceancolor.gsfc.nasa.gov/ and the OEB Research website at http://neptune.gsfc.nasa.gov/osb/.

The work within the OEB is funded through multiple flight projects and NASA research awards (e.g., Research Opportunities in Space and Earth Sciences, ROSES). Both the flight project support and research efforts associated with the OEB are lead by a small group of NASA scientists (within the branch or related organizations at GSFC), with most of the work currently and historically performed by on-site Contract staff. Contract staff are also relied upon to lead or substantially contribute to proposals for new and follow-on funding sources (e.g., responses to ROSES announcements). The scope of work to be performed by the Contractor team spans the following functional areas:

1. **Satellite Sensor Radiometric Calibration.** The Contractor shall perform radiometric calibration analyses of ocean color sensors, including prelaunch sensor calibration and characterization (e.g., laboratory test design and configuration, assessment of response versus scan angle, polarization sensitivity, temperature sensitivity, stray-light contamination, and spectral response), on-orbit calibration (e.g., solar and lunar-based calibration and maintenance and application of the Robotic Lunar Observatory model) and assessment of sensor radiometric stability over time. The Contractor shall perform routine monitoring and maintenance of instrument radiometric performance for currently operating sensors (e.g., MODIS), as well as periodic reassessment of instrument radiometric characterization over the full mission lifespan prior to reprocessing of any operational or legacy ocean color mission. The Contractor shall further develop and implement additional calibration methods and techniques as needed to augment the prelaunch and on-board calibration capabilities (e.g., cross-calibration between satellite sensors, vicarious calibration between satellite sensors and ground-based targets). This work will include interfacing with external sensor calibration teams (e.g., the MODIS Calibration Support Team, MCST), with the goal being to monitor and mitigate the impact of calibration changes and sensor degradation on ocean color products. The Contractor shall also develop radiometric requirements and prelaunch test plans to support new satellite sensors (e.g., for an advanced ocean color sensor for the PACE mission).

2. **Scientific Software and Algorithm Development.** The Contractor shall develop and implement processing algorithms and software to produce ocean color, SST, SSS and Wind Speed products from remote sensing instruments. This involves development, maintenance, and configuration management of the scientific software (currently more than 100 executables, 500000 lines of code, mixed C, C++, and Fortan) to process satellite radiometric observations from observed counts to calibrated, global geophysical products. The processing algorithms may be provided in the form of Algorithm Theoretical Basis Documents (ATBDs) or prototype code from Science Team members or the research community, or developed by the Contractor or other OEB staff. In the case of Aquarius, the primary geophysical product algorithm developer is the Aquarius Science Team while the Level-0 to Level-1a and Level-3 algorithms are OEB-staff developed. Similarly, the MODIS SST algorithm is

currently the responsibility of the MODIS Science Team. For ocean color retrieval, defined here as the spectral distribution of reflected sunlight upwelling from beneath the ocean surface in the visible to short-wave infrared spectral regime (possibly extending to the ultraviolet for future sensors), the OEB has primary responsibility for the algorithms to produce this water-leaving reflectance from observed radiances, as well as responsibility for some key bio-optical algorithms. The Contractor shall develop and maintain atmospheric correction algorithms to remove the effects of the atmosphere from satellite sensor observations and retrieve the ocean color signal. This includes atmospheric radiative transfer analyses to produce and improve corrections for aerosols, air molecules, and atmospheric gases, as well as surface and subsurface effects (e.g., bi-directional reflectance, sun glint). The Contractor shall also develop and/or implement and evaluate bio-optical algorithms to retrieve biological or biogeochemical water-column constituents (e.g., chlorophyll concentration, diffuse attenuation, inherent optical properties) from satellite ocean color retrievals. In support of new ocean color mission development (e.g., ACE/PACE, GEO-CAPE), the Contractor shall develop atmospheric correction and bio-optical algorithms to exploit the anticipated capabilities of these advanced sensor concepts (e.g., hyperspectral, geostationary).

3. **SeaDAS Support.** The Contractor shall develop, maintain, distribute, and provide user support for the SeaWiFS Data Analysis System (SeaDAS). SeaDAS provides the research community with a tool for display and analysis of all satellite products produced by the OEB, as well as the processing software to reproduce those products, alternative products, or user-developed products from satellite radiometric observations. The Contractor shall maintain the existing capabilities of SeaDAS, ensure software portability with popular operating systems, incorporate new capabilities as needed to support new missions and changing NASA requirements, and evolve the software package through new technologies and design improvements to minimize maintenance costs and enhance utility. The Contractor shall also prepare SeaDAS training materials and lead periodic training workshops for the user community.

4. **Satellite Product Validation and Quality Control.** The Contractor shall provide an assessment of the quality of all standard ocean color products that NASA distributes, to include absolute accuracy, precision, temporal and spatial stability, and mission-to-mission continuity and consistency (where applicable). The Contractor shall perform these assessments immediately prior to any reprocessing or new product generation, and inform the research community as to any change in quality prior to distribution. The Contractor shall also perform quality assessments and comparative analyses of ocean color time-series products to assess performance of new algorithms (proposed by OEB staff or the research community) or sensor calibration changes. The Contractor shall further perform daily assessment of recently processed data (i.e., newly produced MODIS ocean color or SST products) to identify processing errors. Common methods of assessment include comparison with field data (match-ups or in situ time-series trends), product time-series anomaly analyses, and sensor-to-sensor

comparative analyses, but the Contractor shall also investigate new methods to better assess data quality and consistency.

5. **Satellite Data Processing and Distribution.** The Contractor shall enhance, maintain, and operate the Ocean Data Processing System (ODPS), and manage the routine data acquisition and processing, test processing, reprocessing, and distribution of all satellite data and derived products handled by the OEB (e.g., ocean color from MODIS, SeaWiFS, MERIS, OCTS, and CZCS, SST from MODIS, and SSS and Wind Speed products from Aquarius). The ODPS is a processing control system implemented with SyBASE, which supports the scheduling and distribution of processing jobs over many processing servers. The Contractor shall enhance the ODPS and data distribution capabilities of the OEB to support new missions and requirements (e.g., VIIRS, ACE/PACE) or evolving international collaborations.

6. **NPP VIIRS Support.** The activities of the OEB in support of NPP VIIRS include operation of the NPP Ocean PEATE and participation in the VIIRS Ocean Science Team (VOST). The Ocean PEATE is one of the elements of the Science Data Segment (SDS) of NPP. The primary role of the NPP SDS is to assess the quality of the NPP Environmental Data Records (EDRs) for climate research. EDRs are the official products produced by the Interface Data Processing Segment (IDPS) that will be operated by NOAA. The Ocean PEATE supports the VOST by acquiring and distributing selected data sets of VIIRS observed radiometry and derived ocean color and sea surface temperature (SST) Environmental Data Records (EDRs). In support of the VOST, the Contractor shall evaluate the EDRs to determine whether they can provide data continuity for NASA climate data records (CDR). The Contractor shall perform continuous assessment of instrument performance and evaluation of on-orbit radiometric corrections, evaluate the operational algorithm performance relative to the state of the art, and assess the effectiveness of NPP VIIRS calibration/validation activities. It is possible that the OEBs role on NPP VIIRS will expand to include operational processing and distribution within the OBPG, if so directed by NASA Headquarters Program Management. If that occurs, the Contractor shall integrate VIIRS processing and distribution capabilities into the ODPS, including the acquisition and processing of Raw Data Records (RDRs) to Science Data Records (SDRs), the processing of SDRs to higher level data products, and providing the full suite of user support services consistent with current MODIS support.

7. **Satellite Sensor and Mission Development.** The OEB is currently leading the preliminary science and sensor requirements development for the ocean color capabilities of ACE and GEO-CAPE missions. ACE is a mission focusing on Aerosols, Clouds, and ocean Ecosystems that is expected to launch no earlier than 2022. Recently, NASA announced the data continuity PACE (Pre-ACE) mission, with a launch date no earlier than 2019. PACE will contain a sensor to measure ocean color and possibly a French-contributed polarimeter for aerosol measurements. The science requirements for PACE have not yet been defined, but are expected to be similar to those of the ACE mission. The Geostationary Coastal and Air Pollution

Events (GEO-CAPE) mission is being formulated for launch no earlier than 2021. To support the establishment of the ACE/PACE and GEO-CAPE mission requirements for ocean color, the Contractor shall apply in situ measurements and satellite data, and perform radiative transfer simulations to study the spectral, spatial and temporal requirements necessary to accurately retrieve the ocean color signal and to capture the variability of ocean biogeochemical dynamics. It is anticipated that GSFC will be awarded management responsibility for PACE mission and that Contractor requirements within the OEB will expand to include formal mission development support (Phase A: Preliminary Analysis, Phase B: Definition, Phase C: Design, Phase D: Development) as well as prelaunch and on-orbit calibration, software and algorithm development, and development of processing capabilities to produce ocean biological and biogeochemical products from the ocean color sensor on PACE.

8. **Aquarius Instrument Operations.** Aquarius is a spaceborne sensor designed to measure the Sea Surface Salinity (SSS) of the world's oceans on a global scale. Aquarius launched in June 2011 on the SAC-D spacecraft, which was built and is being operated by the Argentine space agency, the Comisión Nacional de Actividades Espaciales (CONAE). NASA provided the Aquarius combined passive microwave radiometer/active radar scatterometer, the launch vehicle, the Aquarius instrument Command and Control System (ACCS), and the Aquarius data processing system (ADPS). JPL had overall Aquarius project management responsibilities in the prelaunch phase, but project management responsibilities will transfer to GSFC after early orbit check-out and a successful Post-Launch Acceptance Review (PLAR). The OEB requires Contractor support for the software development, documentation and ongoing operations of the ACCS and associated instrument operations functions. The Contractor shall coordinate support for SAC-D by NASA's Near Earth Network (NEN) during launch and early orbit operations, special operations, and spacecraft emergencies. This will involve interfacing with NEN and CONAE personnel in order to maintain and update the Project Service Level Agreement (PSLA) and other plans and documents required to arrange this support. The Contractor shall develop and operate the ACCS for Aquarius instrument operations scheduling, instrument commanding and anomaly detection and in support of the Aquarius Instrument Team for anomaly resolution. Close coordination is required with CONAE to resolve issues associated with instrument scheduling and commanding and data transfer from CONAE to GSFC. The Contractor shall respond to any spacecraft/sensor anomalies that may arise, help to diagnose the impact of such an anomaly on both spacecraft operations and data products, and support the Aquarius Instrument Team to return to routine operations with minimal loss of Aquarius data. The Contractor can expect to make two trips to Argentina and two trips to the US west coast (Pasadena, CA) per year (2 people) for approximately one week each for status and coordination discussions with CONAE and JPL.

9. **Field Data Collection and Laboratory Analyses.** To support the satellite ocean color calibration, validation, and bio-optical algorithm development activities within

the Branch, as well as on-going research studying the marine carbon cycle and the interactions and feedbacks between biological (e.g., primary production), chemical (e.g., organic carbon and nutrient balances and fluxes), and physical processes (river discharge, mixed layer dynamics, circulation, etc.), the OEB participates in oceanographic field campaigns and operates laboratory facilities at GSFC to process and analyze water samples for biological and biogeochemical constituents. The Contractor shall participate in multiple oceanographic cruises each year and perform field data collection (e.g., above and below water radiometry, inherent optical properties, water sampling). The Contractor shall provide post-cruise analysis (e.g., processing of radiometric profiles to water leaving radiances, analysis of water samples for phytoplankton pigments, dissolved organic carbon (DOC), particulate organic carbon, and nitrogen, and determination of absorption spectra of particles and colored dissolved organic matter (CDOM). This shall include analysis of water samples collected by external investigators (e.g., to extract phytoplankton pigments concentrations using High Performance Liquid Chromatography), as directed by NASA. Furthermore, the Contractor shall ensure that all water samples are properly handled and stored prior to analysis. The Contractor shall also conduct laboratory experiments (e.g., to determine process rates of microbial degradation of DOC, sunlight photodegradation of CDOM and DOC, and phytoplankton production of DOC). The OEB also hosts one to two workshops each year to train the international research community or to build consensus on oceanographic field data collection and processing protocols, and the Contractor shall organize and conduct these workshops. The Contractor shall also maintain and extend the existing NASA Ocean Optics Protocols that are currently available as NASA Technical Memoranda and distributed through the OCW, to incorporate new or updated instrument capabilities or measurement approaches.

10. **Field Data Archival and Quality Control.** All researchers supported by the NASA Ocean Biology and Biogeochemistry Program (OBB) to collect in situ atmospheric and bio-optical data are required to submit the data to the OBPG for archival in the SeaWiFS Bio-optical Archive and Storage System (SeaBASS). SeaBASS currently includes data from several thousand cruises and hundreds of thousands of stations, and typically receives new submissions from as many as ten investigators each month. SeaBASS utilizes a relational database and provides a user interface that allows users to query the database for very specific information (inherent and apparent optical properties, biological parameters, atmospheric properties, hydrographic variables, time, location, etc.). The Contractor shall maintain the SeaBASS archive and submission system, and process and quality control the data before incorporating it into SeaBASS. The processing includes the derivation of water leaving radiance, surface reflectance, and diffuse attenuation from the optical profile data as well as surface reflectance from above surface observations. The Contractor shall diagnose and quantify possible sources of error in the data and derived products and recommend improvements and corrections to data providers. The Contractor shall support SeaBASS users with data submission and data retrieval. The Contractor shall also utilize the SeaBASS holdings to maintain and enhance the

NASA bio-Optical Marine Algorithm Data set (NOMAD) that contains the field measurements utilized in the derivation and evaluation of bio-optical algorithms within the OBPG and by the international research community.

11. **Ocean Ecosystem and Carbon Budget Modeling.** The Contractor shall develop coupled ocean dynamical-ecosystem-carbon-system models to study the impacts of environmental conditions and climate change on marine ecosystem species composition and abundance, carbon transformations within oceans, ocean acidification, and CO_2 exchange with the atmosphere. This includes coupling with in situ data and satellite remotely sensed data (ocean color, SST, surface winds, etc.) to validate model predictions and support the interpretation of the model results.

12. **User Support and Documentation.** The OEB places a high priority on documentation and communication with the research community. To that end, the Contractor shall monitor and respond to user queries on the Ocean Color Forum of the OCW, which currently receives approximately 200 user posts per month. The Contractor shall maintain a documentation tree on the OCW that details the satellite ocean data processing algorithms and sensor calibration activities. The Contractor shall publish analysis results via the OCW for all proposed reprocessing changes prior to initiation of a reprocessing (OBPG, Aquarius), and report any significant degradation in sensor calibration or product quality as needed to inform the user community of potential impacts to distributed products. The Contractor shall prepare and deliver oral presentations as requested by NASA at several science team meetings and conferences each year. This will likely include local meetings of the MODIS and NPP Science Teams, national meetings of the NASA Ocean Biology and Biogeochemistry Program, national and international ocean science conferences such as ASLO, AGU, and Ocean Optics, and engineering conferences such as the annual meeting of the Society of Photo-Optical Instrument Engineers (SPIE) in San Diego. Typically, one to three talks will be presented by OEB Contract staff at each meeting. The Contractor shall publish descriptions of innovative methods and analyses (e.g., calibration methods, algorithm advancements, changes in satellite product quality due to reprocessing), advancements in satellite and field instrument development, and laboratory and field measurement protocols in NASA Technical Memoranda, conference papers (e.g., SPIE, Ocean Optics), and refereed journals (e.g., Applied Optics, Remote Sensing of Environment, typically 2-4 papers per year).

13. **Systems Administration.** The Contractor shall provide systems administration support for all government-provided computing equipment used in the satellite data processing and related analysis activities (i.e., OBPG, NPP/VIIRS Ocean PEATE, Aquarius, and new mission development). This currently includes approximately 45 Desktop and laptop systems (Linux and Macintosh), 65 dedicated ODPS processing servers (Linux), and 110 data storage servers (totaling nearly three Petabytes), as well as a high-speed internal network and external networking interfaces. The Contractor shall understand, interpret and implement all network and system security procedures required by NASA/Goddard Space Flight Center, and provide routine maintenance,

data integrity, system upgrades, and problem resolution. The Contractor must also be able to respond to changing NASA requirements (e.g., new missions, expanding data volumes, and enhanced processing needs), and provide evaluation and implementation support for the smooth transition of new technology to meet those changing requirements. Historically, roughly 50% of the ODPS processing servers and storage systems have been replaced or repurposed every 18 months, resulting in significant increases in storage capacity and processing throughput. The Contractor shall provide systems engineering and market research to identify hardware and software to be acquired, support the development of procurement specifications, install and configure new hardware and software, and repurpose existing hardware and software within the OEB.

14. **Office and Laboratory Management.** The Contractor shall provide laboratory and office management support for OEB laboratory facilities in GSFC building 22 and OEB offices in GSFC building 28. This support includes interfacing with GSFC facilities management for personnel access, telecommunications, and power and space requirements, management of office equipment and furnishings, coordination of visitor access for on-site meetings, and logistical support for packing, shipping, and receiving needs. The Contractor shall provide logistical support for meetings and workshops hosted by OEB staff. The Contractor shall maintain an inventory of all OEB property, including tagged property numbers, location, and assigned user, and coordinate the excessing of unneeded equipment through GSFC property management. The Contractor shall be responsible for the transportation and maintenance of all laboratory and field equipment to support field campaigns and other activities (e.g., instrument workshops, manufacturer calibrations). Transportation includes the proper scheduling, packing, and inventorying of all equipment shipments, including the timely submission of completed paperwork to the shipping authority. All shipments shall be tracked and potential non-delivery of a shipment shall be identified promptly with recommendations for corrective measures. The Contractor shall perform routine maintenance of all laboratory and field equipment (replacement parts, arrangements for recalibrations, etc.) and other materials required to support the field and laboratory data collection and analyses (glassware, filter pumps, shipping containers, etc.). Maintenance includes timely adherence to a maintenance schedule, identifying which components require refurbishment or replacement and contracting for the work to be done, and ensuring all field instruments are cleaned and inspected subsequent to each deployment.

In order to comply with the Section 508 Electronic and Information Technology Accessibility Standards, the contractor shall perform all work required under this contract in compliance with the following technical standards delineated in Code of Federal Regulations (CFR) Title 36:

1194.21 Software Applications and Operating Systems
1194.22 Web-based Intranet and Internet Information and Applications